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(54) Scanning device comprising a rotatable mirror, drive unit for use in the scanning device, and rotor body.

(57) A scanning device comprises a rotatable mirror and a drive unit. The drive unit comprises a rotor section which carries the mirror and which is rotatable about an axis of rotation (19), which rotor section has a disc-shaped at least partly permanent-magnetic rotor body (13). The drive unit further comprises a stationary stator section with coils (9) extending in the magnet field of the rotor body to generate electromagnetic driving forces acting on the rotor body to provide the rotary drive of the mirror, and coils (11) disposed in the magnet field of the rotor body to generate electromagnetic bearing forces acting on the rotor body, for electromagnetically supporting the rotatable rotor section relative to the stator section.

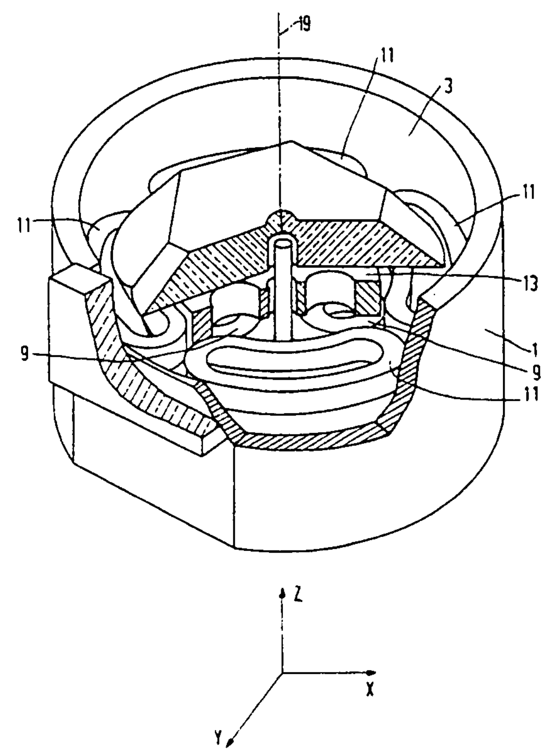

FIG.3

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The invention relates to a scanning device comprising a rotatable mirror for directing and aiming a radiation beam at a surface to be scanned and a drive unit comprising a rotor section carrying the mirror and supported so as to be rotatable about an axis of rotation, which rotor section comprises a cylindrical, in particular disc-shaped, at least partly permanent-magnetic rotor body and a stationary stator section with coils extending into the magnet field of the rotor body, for generating electromagnetic driving forces acting on the rotor body to provide the rotary drive of the rotor section

Such a scanning device is known from Japanese Kokai 61-147218 (herewith incorporated by reference). The known scanning device comprises a brushless electric motor having a stator with coreless flat coils. The electric motor has a rotor with two axially magnetized permanent magnets and mirror segments arranged at the circumferential surfaces of the magnets. The prior-art scanning device further comprises a centrally arranged mechanical bearing, in particular an air bearing, to support the rotor for rotation about an axis of rotation. The bearing has gaps between the bearing surfaces in which compressed air is introduced by means of a pumping device. A drawback of the prior-art scanning device is the presence of the air bearing, in which such a turbulence can develop at high rotor speeds that an unstable bearing condition arises. However, for many uses of scanning devices comprising polygonal mirrors high speeds and stable bearing arrangements are required. A further drawback of the known scanning device is that in the course of time contamination in the bearing gives rise to wear of the bearing. Another drawback is that on account of the accuracy requirements imposed on it an air bearing is comparatively difficult to manufacture and is therefore comparatively expensive.

It is an object of the invention to provide a scanning device of the type defined in the opening paragraph which does not have said drawbacks.

To this end the scanning device in accordance with the invention is characterized in that the stator section of the drive unit comprises coils disposed in the magnet field of the rotor body, for generating electromagnetic bearing forces acting on the rotor body to support the rotatable rotor section electromagnetically relative to the stator section.

As a result of the electromagnetic bearing created in the scanning device in accordance with the invention the rotor section carrying the mirror freely rotates without mechanical contact in the energized condition of the coils. In the case of a suitable configuration of coils for generating electromagnetic bearing forces and suitable energizing currents through the coils for generating the electromagnetic bearing forces a stable bearing system with a fixed axis of rotation can be obtained. By energizing the coils for generating electromagnetic bearing forces before the coils for generating electromagnetic driving forces are energized, it is ensured that when the rotor section is set into rotation there is no mechanical contact between the rotor section and the stator section. The electromagnetic bearing formed by the coils for generating electromagnetic bearing forces and the rotor body provides trouble-free operation and is easy to manufacture owing to its simple construction.

The scanning device in accordance with the invention is very suitable for scanning magnetic recording tracks or recording marks on an elongate carrier or tape by means of a radiation beam.

An embodiment of the scanning device in accordance with the invention is characterized in that the scanning device comprises a position and orientation measurement system comprising at least one detector for measuring the position and orientation of the mirror and for generating signals, a matrix circuit being provided for selectively driving the coils for generating electromagnetic bearing forces defending upon said signals.

Said measurement system in conjunction with the matrix circuit enables the coils for generating eletromagnetic bearing forces to be driven in such a way that, viewed in a system of orthogonal axes whose origin is situated in the mirror and of which one of the axes, the Z-axis, coincides with the axis of rotation, it is possible to move the axis of rotation of the mirror along the X-axis, the Y-axis and the Z-axis and to tilt said axis of rotation about the x-axis and the y-axis. The remaining movement possibility in accordance with a sixth degree of freedom, namely a rotation about the Z-axis, is obtained by energizing the coils for generating the electromagnetic driving forces.

Depending on specific requirements the position and orientation measurement system of the scanning device in accordance with the invention may be adapted to measure the position and orientation of the mirror relative to the surface to be scanned, in particular recording tracks or marks, and/or relative to the stator section of the drive arrangement. If the measurement system is adapted to measure the position and the orientation of the mirror relative to the surface to be scanned possible deviations in the orientation of the surface to be scanned, for example as a result of inaccuracies in the guidance construction of the carrier of the surface to be scanned can be compensated for automatically by tilting and/or translating the axis of rotation. By constantly measuring the orientation of the rotor section or the mirror relative to the stator section any deviations of the position of the axis of rotation relative to a predetermined axis can be compensated for electronically. A combination of

said measurements is also possible. Hereinafter, the position and orientation measurement system is also referred to briefly as the position measurement system.

Said measurement system and said matrix circuit form part of an electronic control circuit of the scanning device. In order to preclude instabilities of the control system it is important to avoid crosstalk within the circuit whenever possible. For this purpose the measurement system preferably comprises a plurality of detectors, which operate independently or substantially independently of one another, for measuring the position and orientation of the mirror and for generating signals. The number of detectors is determined, in principle, by the number of desired correction possibilities with respect to the position and orientation of the axis of rotation and is preferably five.

An embodiment of the scanning device in accordance with the invention is characterized in that the coils for generating electromagnetic bearing forces are segmental coils and are arranged in sets of segmental coils which are juxtaposed viewed in the circumferential direction in the rotor body, the sets of segmental coils each comprising at least two segmental coils which are arranged in line viewed along the axis of rotation of the rotor section.

The stationary segmental coils are spaced at some distance from the rotor body and cooperate magnetically with the rotor body via an air gap. In the case of selective energization of the segmental coils it is possible to produce three forces directed along the three coordinate axes of a system of orthogonal axes and two torques acting about two of said coordinate axes. The segmental coils, which generally have a substantially banana-like arcuate shape, can be manufactured simply and occupy a comparatively small amount of space. The segmental coils can be constructed as coils having one active coil section which is situated opposite the rotor body, which extends in the circumferential direction of the rotor body and which cooperates magnetically with the rotor body, and passive coil sections which are situated substantially farther from the rotor body and which are immaterial in the generation of electromagnetic forces. It is also possible to have segmental coils comprising two parallel active coil sections which extend in the circumferential direction of the rotor body and which viewed along the axis of rotation are disposed in line, which active coil sections are connected by passive coil sections. Moreover, further modifications and combinations of segmental coils are possible. In general, the rotor body will then be axially magnetized at least partly although suitable coil configurations in conjunction with an at least partly radially or otherwise magnetized stator body are possible.

An embodiment of the scanning device in accordance with the invention which is attractive for reasons of symmetry and efficiency is characterized in that the number of sets of segmental coils is at least four.

An embodiment of the scanning device in accordance with the invention in which the rotor section can rotate perfectly freely in space, without requiring the use of additional bearing means such as stator magnets, is characterized in that the rotor section of the drive unit is supported exclusively electromagnetically.

An embodiment of the scanning device in accordance with the invention, in which the rotor body at least partly exhibits a permanent axial magnetization and in which the coils for generating electromagnetic driving forces are disposed in a plane which is oriented transversely of the axis of rotation of the rotor body of the drive unit, is characterized in that the rotor body comprises non-magnetic portions, or magnetic portions having a direction of magnetization opposite to that of the remainder of the rotor body, which portions are situated opposite the coils for generating electromagnetic driving forces, which portions are spaced at a radial distance from the circumferential surface of the rotor body and which portions are tangentially bounded and extend axially in the rotor body.

The rotor body of this scanning device is very suitable or magnetic cooperation with both the coils for generating electromagnetic bearing forces and the coils for generating electromagnetic driving forces. Since the non-magnetic portions or said magnetic portions do not extend up to the circumferential surface of the rotor body the magnetic field is highly uniform in a zone around the circumferential surface of the mechanically strong rotor body. This has the advantage that the coils for generating electromagnetic bearing forces are also disposed in a substantially constant magnet field during rotation of the rotor section, which is beneficial for the bearing characteristics.

A simple to realise embodiment of the scanning device in accordance with the invention is characterized in that the non-magnetic portions are formed by regularly spaced holes which extend axially in the rotor body. Depending on specific requirements the holes may be through-holes or pot-holes and can be formed by means of a suitable drilling tool during manufacture, preferably prior to magnetization of the rotor body.

Another embodiment of the scanning device in accordance with the invention in which the rotor body at least lpartly exhibits an axial permanent magnetization and in which the coils for generating electromagnetic driving forces are disposed in a plane which is oriented transversely of the axis of

rotation of the rotor section of the drive unit, is characterized in that the rotor body comprises non-magnetic portions situated opposite the coils for generating electromagnetic driving forces and adjoining the circumferential surface of the rotor body, which portions are bounded in a tangential direction and extend axially in the rotor body. In this embodiment, in which the rotor body has to be magnetized in only one direction during manufacture, the coils for generating electromagnetic bearing forces are situated in a fluctuating magnet field during rotation of the rotor section. However, the resultant fluctuations can be compensated for easily by electronic means.

An embodiment of the scanning device in accordance with the invention, in which the coils for generating electromagnetic driving forces are disposed in a plane which is oriented transversely of the axis of rotation of the rotor section of the drive unit, and in which the rotor body comprises first and second magnetic portions having opposite directions of magnetization, which portions are situated opposite the coils for generating electromagnetic driving forces, which adjoin the circumferential surface of the rotor body, which are bounded in the tangential direction and which extend axially in the rotor body, the first magnetic portions together forming a first part of the circumferential length of the circumferential surface and the second magnetic portions together forming a second part of the circumferential length of the circumferential surface of the rotor body is characterized in that the first part of the circumferential length is unequal to the second part of the circumferential length of the circumferential surface of the rotor body.

In contradistinction to the axially magnetized rotor body known from the Japanese Kokai 61-147218 the rotor body in the last-mentioned embodiment of the scanning device in accordance with the invention has a non-zero average magnetic field strength viewed along the circumferential surface of the rotor body, so that the rotor body in the scanning device in accordance with the invention can cooperate effectively both with the coils for generating electromagnetic driving forces and with the coils for generating electromagnetic bearing forces.

For reasons of production engineering and for reasons of mechnical strength it is preferred to manufacture the rotor body from one piece of a material. This is of particular importance if very high speeds of rotation of the mirror are envisaged.

An embodiment in which the number of coils is to be minimized is characterized in that at least a number of the coils are constructed as combination coils which function both as coils for generating electromagnetic driving forces and as coils for generating electromagnetic bearing forces. The rotor body in this embodiment may be an axially magnetized cylindrical body of elliptical or similar cross-section.

An embodiment of the scanning device in accordance with the invention is characterized in that there is provided an evacuated chamber in which at least the mirror and the mirror-carrying rotor section of the drive unit are arranged. This embodiment utilizes the afore-mentioned advantages of the scanning device in accordance with the invention to an optimum extent. Since the rotor section is situated in the evacuated chamber it is possible to attain high accelerations and high speeds of the mirror, in particular a polygonal mirror. The partial vacuum prevailing in the chamber mitigates the production of noise, erosion and pollution of the drive unit. Moreover, the loss of energy in the scanning device comprising the evacuated chamber is very small as a result of the complete absence of mechanical friction and the almost absent of air resistance.

It is to be noted that it is known per se from British Patent Application 2,023,964 (herewith incorporated by reference) to arrange a rotatable mirror, a bearing arrangement for the mirror and a motor for driving the mirror in an enclosed evacuated space. However, said British Patent Application does not give any details about the bearing arrangement and the motor.

The invention also relates to a drive unit for use in the scanning device in accordance with the invention and to a rotor body for use in the drive unit.

The invention will now be described in more detail, by way of example, with reference to the drawings, in which

Fig. 1 is a longitudinal sectional view of a part of the scanning device in accordance with the invention comprising a rotatable mirror,

Fig. 2 is a sectional view taken on the line II-II in Fig. 1,

Fig. 3 is a perspective view showing a part of the scanning device and the drive unit therein shown in Fig. 1,

Fig. 4 is a perspective view of the rotor body of the drive unit in the scanning device shown in Fig. 1,

Fig. 5 is a circuit for use in the scanning device shown in Fig. 1,

Fig. 6 is a perspective view showing a first modification of the rotor body shown in Fig. 4,

Fig. 7 shows a second modification of the rotor body,

Fig. 8 shows a third modification,

Figs. 9a and 9b show a fourth modification, and

Fig. 10 shows a position measurement system for stabilizing the rotatable mirror during operation.

The scanning device in accordance with the invention shown in Figs. 1, 2 and 3 comprises a housing 1, which forms an enclosed evacuated chamber 3 in which for example a pressure of 10^3 Pa prevails. The housing accommodates an electrical drive unit comprising a stator section 5 and a rotor section 7. The stator section 5, which is secured to the inner side of the housing 1 or which is integral therewith, comprises two groups of coils bearing the reference numerals 9 and 11 respectively. The rotor section 7 comprises a permanent magnet rotor body 13 and a polygonal mirror 15 connected thereto. The rotor body 13 is constructed as a flat cylindrical axially magnetized permanent magnet formed with a regular pattern of three axial holes 17 (see also Fig. 4). The rotor body 13 together with the mirror 15 is rotatable about an axis of rotation 19, the polygonal mirror 15 serving to direct and aim a beam issuing from a radiation source at a surface to be scanned optically of for example a strip-shaped or ribbon-shaped carrier. In order to achieve a high scanning speed (for example 60 m/s) at a low carrier speed (for example 0.6 cm/s) a very high speed of rotation of the polygonal mirror (for example 180.10^3 rpm) is necessary. The scanning device in accordance with the invention is very suitable for rotating the polygonal mirror with such a speed.

The coils 9 of the stator section 5 are coils for generating electromagnetic driving forces acting on the rotor body 13 and are commutated electronically. The coils 9 are constructed as flat annular coils disposed in a plane which is oriented perpendicularly to the axis of rotation 19. The scanning device shown has four coils 9 which, when energized cooperate with the rotor body 13 to rotate the rotor section 7. The coils 11 serve for generating electromagnetic bearing forces acting on the rotor body 13 for electromagnetically supporting the rotor section 7 relative to the stator section 5. The coils 11 are constructed as segmental coils, in particular arcuate banana-shaped segmental coils, and are arranged in four sets of two coils each. Viewed in the circumferential direction A of the rotor body 17 the sets are juxtaposed in a regular manner, the coils with in the sets being disposed in line with one another viewed along the axis of rotation 19. The coils 11 for generating electromagnetic bearing forces are disposed in the magnet field of the rotor body 13 and, when suitably driven, they can exert such electromagnetic bearing forces on the rotor body 13 that the rotor section 7 is supported to float freely in the chamber 3. Upon energization of the coils 9 for generating electromagnetic driving forces the freely floating rotor section 7 thus obtained can be set into rotation about the axis of rotation 19 and this rotation can be sustained without mechnical contact being made with the stator section 5. In order to keep the rotor body 13 and the polygonal mirror 15 in a more or less centred position in the non-energized condition of the coils a centring pin 10 which projects into an opening 8 in the rotor section 7 with ample clearance may be arranged in the housing. The device may comprise a stationary magnet in order to compensate for the force of gravity acting on the rotor section.

In order to guarantee a stable bearing arrangement and to provide the possibility of slightly translating and/or tilting the axis of rotation the scanning device in accordance with the invention comprises a position and orientation measurement system, briefly referred to as position measurement system, and a matrix circuit for selectively driving the coils so as to generate electromagnetic bearing forces acting on the rotor body.

Fig. 3 shows a system of orthogonal axes X, Y, Z whose origin O is assumed to be situated in the mass centre of the polygonal mirror 15, so that the Z axis coincides with the axis of rotation 19. The six theoretically possible independent degrees of freedom of the rotor section 7, and hence of the mirror 15, comprise translations along the X-axis, Y-axis and Z-axis and rotations or pivotal movements about these axes. The translations along the X-axis, Y-axis and Z-axis and the pivotal movements about the X-axis and the Y-axis of the mirror 15 are of importance in relation to the coils 11 of the electromagnetic bearing arrangement. The rotation about the Z-axis is of importance with respect to the coils 9 of the rotary drive. The signals from a position measurement system 2 (Fig. 5) relate to the translations along the X-axis, Y-axis and Z-axis and the pivotal movements about the X-axis and the Y-axis, and in Fig. 5 they are indicated by Sx, Sy, Sz, Sα and Sβ respectively. The signals are applied to a matrix circuit 27 via amplifers 23 and lead networks 25, in which circuit the signals are converted into suitable control signals. By means of eight current sources 29 the eight coils 11 are energized to generate the electromagnetic bearing forces acting on the rotor body 13.

The measurement system 21 comprises five detectors operating substantially independently of one another, in such a way that each position signal Sx, Sy, Sz, Sα and Sβ corresponds to one degree of freedom of the mirror 15. These five degrees of freedom comprise translations along the three axes (X-axis, Y-axis and Z-axis) and pivotal movements about the X-axis and the Y-axis of the system of orthogonal axes shown in Fig. 3. Said matrix circuit 27 is constructed in such a way that the signals applied thereto are transferred in such a manner that the electric current through the segmental coils 11 for generating electromagnetic bearing forces essentially produces a correction

characterized in that the rotor body comprises non-magnetic portions, or magnetic portions having a direction of magnetization opposite to that of the remainder of the rotor body, which portions are situated opposite the coils for generating electromagnetic driving forces, which portions are spaced at a radial distance from the circumferential surface of the rotor body, and which portions are tangentially bounded and extend axially in the rotor body.

7. A scanning device as claimed in Claim 6, characterized in that the non-magnetic portions are formed by regularly spaced holes which extend axially in the rotor body.

8. A scanning device as claimed in Claim 1, 2, 3, 4 or 5, in which the rotor body at least partly exhibits an axial permanent magnetization, and in which the coils for generating electromagnetic driving forces are disposed in a plane which is oriented transversely of the axis of rotation of the rotor section of the drive unit, characterized in that the rotor body comprises non-magnetic portions situated opposite the coils for generating electromagnetic driving forces and adjoining the circumferential surface of the rotor body, which portions are bounded in a tangential direction and extend axially in the rotor body.

9. A scanning device as claimed in Claim 1, 2, 3, 4 or 5, in which the coils for generating electromagnetic driving forces are disposed in a plane which is oriented transversely of the axis of rotation of the rotor section of the drive unit, and in which the rotor body comprises first and second magnetic portions having opposite directions of magnetization, which portions are situated opposite the coils for generating electromagnetic driving forces, which adjoin the circumferential surface of the rotor body, which are bounded in the tangential direction and which extend axially in the rotor body, the first magnetic portions together forming a first part of the circumferential length of the circumferential surface and the second magnetic portions together forming a second part of the circumferential length of the circumferential surface of the rotor body, characterized in that the first part of the circumferential length is unequal to the second part of the circumferential length of the circumferential surface of the rotor body.

10. A scanning device as claimed in any one of the Claims 1 to 10, characterized in that the rotor body is manufactured from one piece of a material.

11. A scanning device as claimed in Claim 1, 2, 3, 4 or 5, characterized in that at least a number of the coils are constructed as combination coils which function both as coils for generating electromagnetic driving forces and as coils for generating electromagnetic bearing forces.

12. A scanning device as claimed in any one of the preceding Claims, characterized in that there is provided an evacuated chamber in which at least the mirror and the mirror-carrying rotor section of the drive unit are arranged.

13. A drive unit for use in a scanning device as claimed in Claim 1 or any one of the Claims 3 to 12.

14. A rotor body for use in the drive unit of the scanning device as claimed in any one of the Claims 6 to 10.

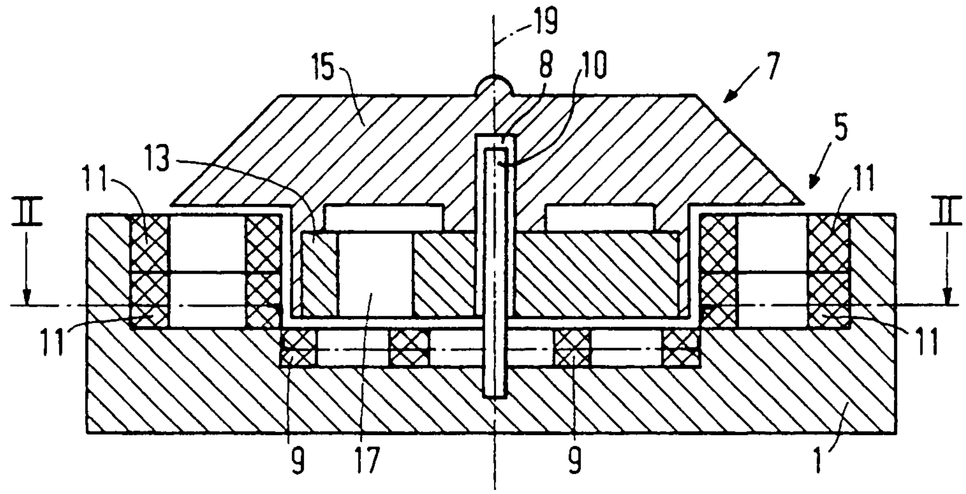

FIG.1

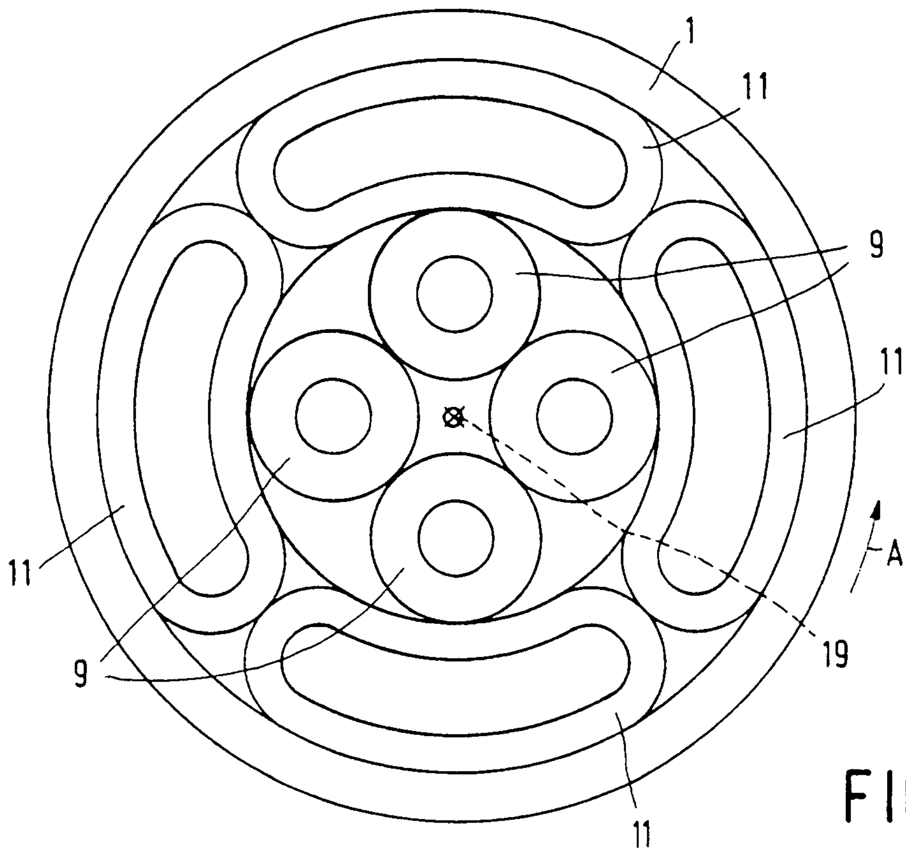

FIG.2

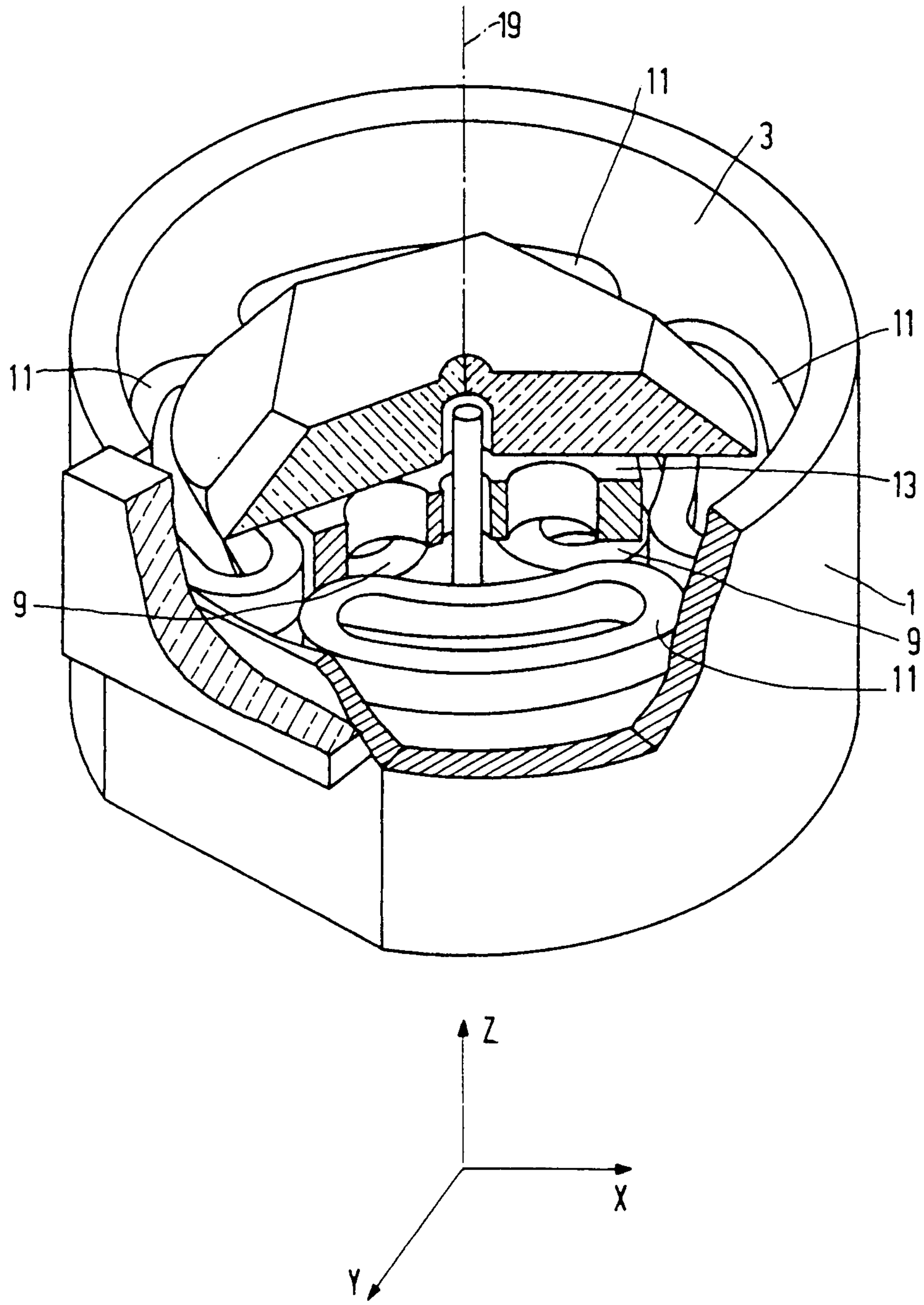

FIG.3

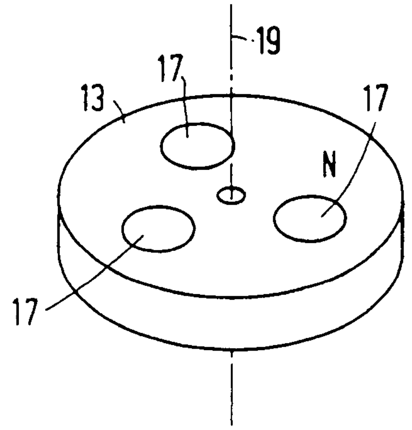

FIG. 4

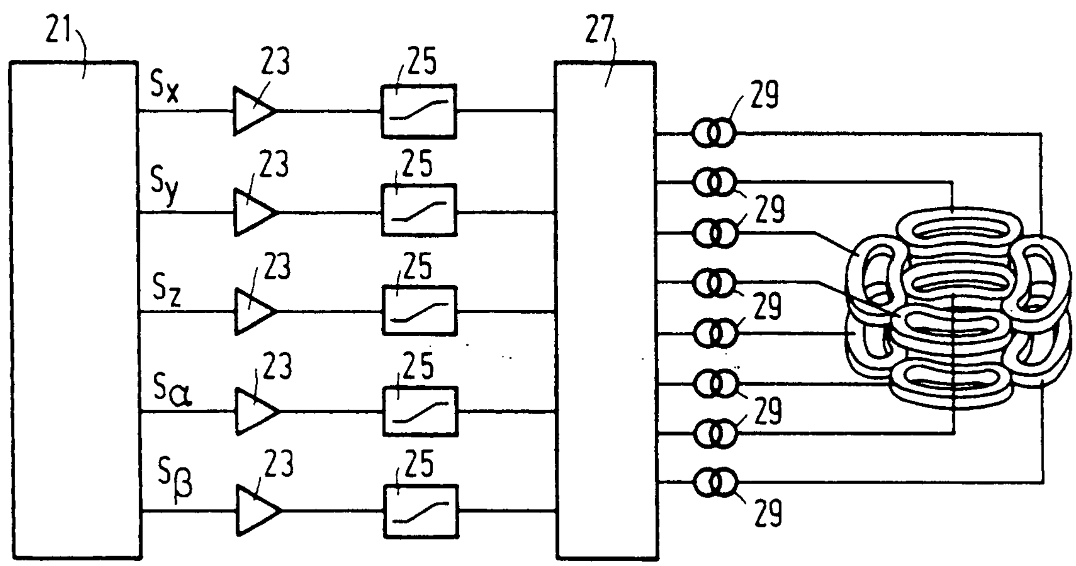

FIG.5

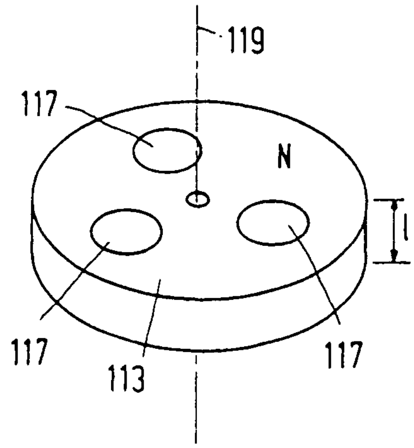

FIG.6

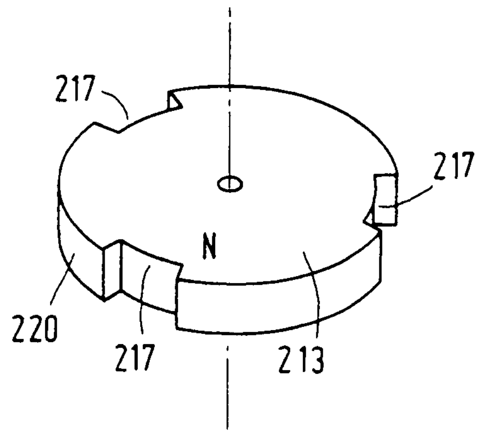

FIG.7

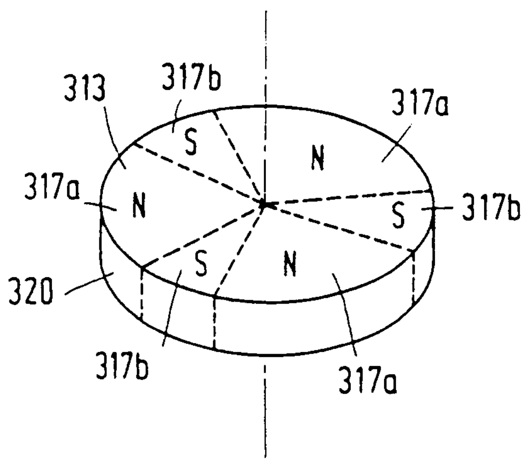

FIG.8

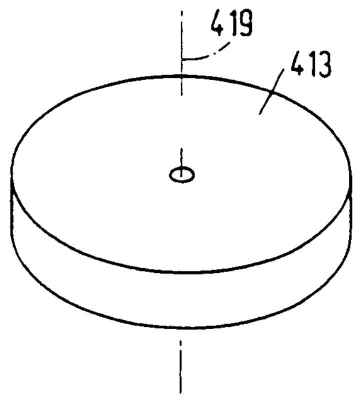

FIG.9a

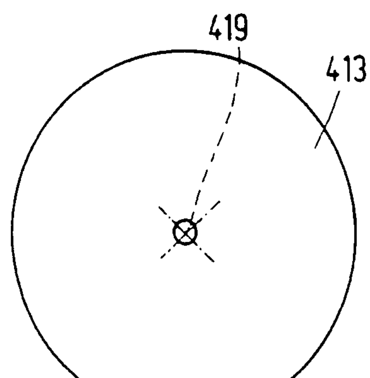

FIG.9b